

Title: Satellite-Scale Snow Water Equivalent Assimilation into a High-Resolution Land Surface Model, Journal of Hydrometeorology (American Meteorological Society)

Author list w/ email addresses:

G. De Lannoy	GDLannoy@cola.iges.org
R. H. Reichle	Rolf.Reichle@nasa.gov
Paul R. Houser	Houser@iges.org
Kristi R. Arsenault	Kristi@cola.iges.org
Niko E.C. Verhoest	Niko.verhoest@UGent.be
Valentijn R.N. Pauwels	VPauwels@taoren.ugent.be

Abstract:

An ensemble Kalman filter (EnKF) is used in a suite of synthetic experiments to assimilate coarse-scale (25 km) snow water equivalent (SWE) observations (typical of satellite retrievals) into fine-scale (1 km) model simulations. Coarse-scale observations are assimilated directly using an observation operator for mapping between the coarse and fine scales or, alternatively, after disaggregation (re-gridding) to the fine-scale model resolution prior to data assimilation. In either case observations are assimilated either simultaneously or independently for each location. Results indicate that assimilating disaggregated fine-scale observations independently (method 1D-F1) is less efficient than assimilating a collection of neighboring disaggregated observations (method 3D-Fm). Direct assimilation of coarse-scale observations is superior to a priori disaggregation. Independent assimilation of individual coarse-scale observations (method 3D-C1) can bring the overall mean analyzed field close to the truth, but does not necessarily improve estimates of the fine-scale structure. There is a clear benefit to simultaneously assimilating multiple coarse-scale observations (method 3D-Cm) even as the entire domain is observed, indicating that underlying spatial error correlations can be exploited to improve SWE estimates. Method 3D-Cm avoids artificial transitions at the coarse observation pixel boundaries and can reduce the RMSE by 60% when compared to the open loop in this study.

Popular Summary:

Satellites can indirectly measure the amount of snow that is present on the land surface. The measurement principle involves an analysis of the electromagnetic radiation in the microwave frequency range (centimeter wavelengths) that is naturally emitted by the land surface. Due to the characteristics of the satellite instruments and the measurement technique, the satellite observations can only provide information about the average snow amount within areas of about 25 km by 25 km. Such coarse-scale information is of limited value for water resources applications, particularly in mountainous areas. Complementary information on snow amounts can be obtained by using estimates of land surface characteristics (such as topography, vegetation, and soil information) along with precipitation (and other surface meteorological information) in a numerical model of land surface processes. The model keeps track of the water and energy balance at the land

surface and thereby also estimates snow amounts. Model estimates of snow can be obtained at relatively fine scales by setting up the numerical model on a 1 km by 1 km grid.

Both the satellite observations and the model estimates are affected by necessary simplifications in the respective computational algorithms and by errors in the corresponding input data. An optimization technique known as “data assimilation” can be used to merge the information from the satellite observations and the land surface model. The resulting estimates are superior to the estimates from the satellite or the land surface model alone. By design, the data assimilation system distributes the coarse-scale satellite information onto the finer-scale model grid, thereby making the satellite observations more useful for water resources applications.

In this paper, we investigate several options for implementing such a data assimilation system. One alternative is to disaggregate the coarse-scale satellite observations to the fine scale of the model prior to data assimilation or within the data assimilation system. Another alternative is for each model location to use only satellite observations that are local to that location or to also use observations from neighboring locations. We test these options for a 75 km by 100 km mountainous area in western Colorado, USA. We find that it is indeed possible to improve fine scale estimates of snow amounts through the assimilation of coarse-scale satellite observations. Our results indicate that it is best (i) to avoid disaggregating the satellite observations prior to data assimilation and (ii) to have satellite observations from the entire domain influence the assimilation estimate at a given location. The most sophisticated assimilation method avoids artificial boundaries around coarse-scale satellite observations and, for our study domain, reduces errors by 60% when compared to the estimates provided by the land surface model alone.